Clutter-Rejection for Obstacle Detection in Radar Data

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Because of its needle-like nose, shaped for supersonic flight, and the high angle of attack used during takeoff and landing, the High-Speed Civil Transport (HSCT) has no forward window. The HSCT would have to rely on synthetic vision for detecting infringing airborne obstacles, and "seeing" the runway during landing and takeoff. The sensor of choice for all-weather operations is an airborne radar. However, there are two problems inherent in utilizing conventional radars for vision: (1) although they excel in resolving range, their angular resolution is rather poor, and (2) ground clutter may be confused with targets of interest, especially when looking down during landing.

Two complementing approaches were employed to solve these problems: first, differentiating between ground clutter (stationary), and airborne obstacles (having a nonzero ground speed); and second, improving the azimuth resolution so as to decrease the effective ground area that generates clutter (the elevation resolution is of no concern, because, in the down-slanted geometry of landing, it can be improved by utilizing high range resolution).

The first approach is to use an Airborne Moving-Target Indicator (AMTI) to discriminate targets by their motion. A new version of AMTI has been developed, which is based on azimuth or elevation error corrections for the equivalent-clutter direction on a pulse-to-pulse basis. The equivalent-clutter direction has been found to wander erratically from pulse to pulse, even for a pulse repetition frequency (PRF) as high as 10,000 per second. However, for each pulse, the clutter directions are highly correlated for adjacent range bins. Thus, the temporal correlation is low, while the spatial one is high. This observation was used to construct an algorithm that, for each pulse, cancels the clutter inside every range bin by utilizing the equivalent-clutter direction in the adjacent bins.

The first figure shows how the signal-to-clutter ratio (SCR) depends on the obstacle's ground speed and on the interpulse interval (T = 1/PRF). Choosing PRF = 10,000 yields a high SCR with a relatively narrow notch of hard-to-detect target speeds.

The difficulty of detecting low-speed targets with AMTI was addressed by modifying a radar-processing technique, called synthetic aperture radar (SAR), which has been in use for ground mapping. Conventional radars have poor angular resolution because of the size limits on the antenna diameter (larger aperture yields better resolution). An SAR can achieve an equivalent large antenna aperture in azimuth by synthesizing it along its flightpath. It

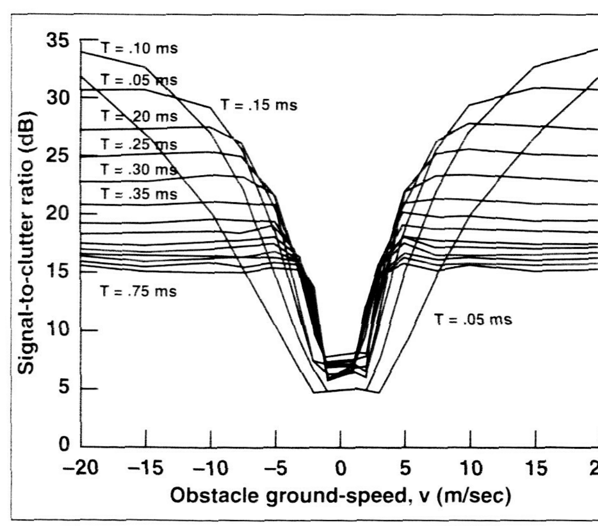

Fig. 1. Obstacle discrimination by ground speed.

illuminates the ground on one side of the aircraft, using a fixed, small, wide-angle antenna. The synthetic aperture equals the distance flown during the observation time of about 0.2 second. Since the aperture is aligned with the flightpath, the conventional SAR is looking sideways at 90 degrees. The SAR technique has been extended for looking "almost forward"; it now illuminates the angular sectors of 5–45 degrees on both sides of the aircraft flight direction. Thus, the azimuthal resolution becomes a variable that depends on the look direction—it is zero looking straight forward, and improves with the squinting angle.

A conventional SAR, as well as the modified one, images stationary reflectors in their correct azimuthal location (range and elevation are always correct), whereas moving targets appear shifted in azimuth in proportion to their ground speed. This phenomenon is apparent in an SAR image of a moving train, where the train appears to run off the tracks. Incorporating a technique called "monopulse" alleviated this problem for *detecting* low-speed targets—although not for their accurate azimuthal *mapping*. The second figure shows the image of a two-dimensional uniform array of point-size reflectors on the ground on the right side of the flightpath (flying left to right). The smearing

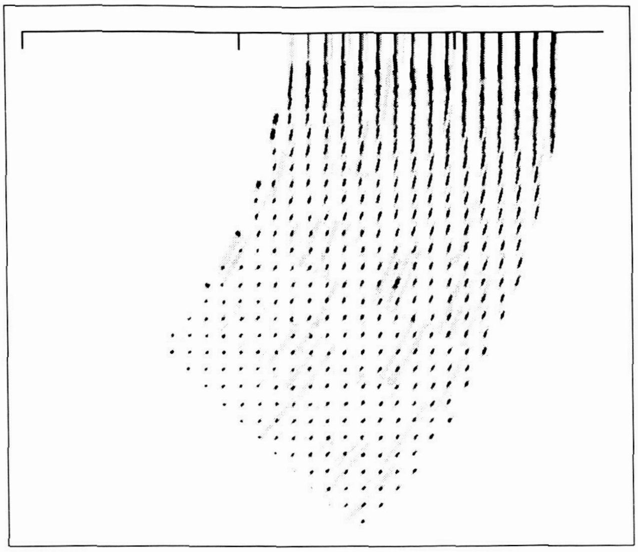

Fig. 2. Azimuthal resolution depends on squint angle.

shows how the resolution degrades as the look angle approaches the flight direction.

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Detection of Aircraft in Video Images

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NASA is collaborating with the aircraft industry to develop technology for a supersonic passenger airplane called the High-Speed Civil Transport (HSCT). One issue that is being examined is the replacement of the conventional forward cockpit windows with synthetic displays. The imagery in these displays would be obtained from video cameras mounted outside the aircraft. A benefit of this configuration is that the video imagery can be examined with computers to determine if another aircraft is in the scene. The goal of this HSCT subproject is to develop computer vision programs to detect aircraft that are moving in the video images.

During FY97, a series of computer programs were written to process video images and to search for moving objects (e.g., other aircraft). Flight tests were conducted in April and May to obtain the video imagery to test the computer programs. Each flight test was conducted with two aircraft. One aircraft was a Boeing 737 with a camera mounted below the nose. With a field-of-view of 13 degrees, this camera recorded the images of a second aircraft (the target plane) flying in various trajectories. For example, one trajectory consisted of the target plane flying from